

AN ENHANCED ELEMENT FORMULATION FOR LARGE ELASTIC DEFORMATIONS USING BIOT STRESSES

Peter Wriggers^a and Mike Crisfield^b

^aInstitut fuer Baumechanik und Numerische Mechanik
Universität Hannover
30167 Hannover, Germany
wriggers@ibnm.uni-hannover.de

^bDepartment of Aeronautics
Imperial College of Science, Technology and Medicine
London, SW7 2BY, U.K.

In structural analysis, many applications involve deformations which are associated with large strains. Furthermore, problems undergoing large elastic strains are often constraint by the incompressibility of the material, as it is the case for rubber. Due to their simple geometry, four-node quadrilateral elements are widely used in such application.

It is well known that the presence of incompressibility leads to the so called ‘locking’ phenomenon in case of a discretization with standard displacement elements. Several methods to circumvent this problem have been developed. These are either reduced integration techniques, or mixed methods. In some approaches rank deficiency of under integrated elements which then leads to hour glassing is bypassed by stabilization techniques. Ten years ago a family of elements has been developed which are called enhanced strain elements and are based on the Hu–Washizu variational principle. These elements are extensions of the incompatible QM6 element. They do not seem to have any rank deficiency and perform well in bending situations as well as in the case of incompressibility. Thus these elements are general applicable.

In the present paper a special version of the Hu–Washizu principle is utilized to derive the underlying equations for the element construction. The main idea is to use a formulation which enhances the stretch tensor \mathbf{U} . Within this approach the enhancement is exactly the same as in the linear theory. This has been pointed out by Crisfield and Moita who applied the enhancement within a co-rotational approach using a constant rotation tensor \mathbf{R} within the element. In the present formulation the latter condition is not enforced, hence the rotations are approximated like the displacements. Based on this assumption all associated matrices are derived for a finite element which is suitable to model large elastic deformations. The formulation is compared with existing formulations by means of numerical examples.